Accumulator Stacktail Upgrade

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Upgrade Philosophy

- Support Maximum stacking rate:
  - Slip Stacking success
  - Lens Upgrade success
  - AP2 & Debuncher Acceptance upgrades success
- Design margin: factor of two
  - 80 mA/hour max

Maximum Flux Calculation

- van der Meer method
  - Exponential gain slope
  - Exponential density
  - Constant Flux
  - Max Flux = $(W^2|\eta|E_d)/(f_o p \ln(F_{max}/F_{min})$
    - W bandwidth, F_{max} and F_{min} frequency range
    - f_o beam revolution frequency, p beam momentum
    - $|\eta|$ phase slip factor
    - E_d characteristic gain slope

Stacktail Design Scenario

- Goal: 80 mA/hour stacking rate in Accumulator
  - x2 design margin above 40 mA/hour
- Accumulate for 30 - 60 minutes, transfer to Recycler
  - Optimize maximum flux, not momentum density
  - Maximum stack size 50-60 mA to avoid falloff in rate
- Change Bandwidth or E_d?

Design Constraints

- Recycler sets longitudinal emittance for transfers (10 eV-sec)
- "long" stacking interval to minimize # of transfers
  - Largest core density
  - Large momentum aperture
  - Small E_d
- Bandwidth better than E_d
  - Larger E_d needs larger momentum aperture for similar core density
  - Momentum aperture defined by frequency range (overlapping Shottky bands) and notch filters

Design Scenarios

Stacktail Bandwidth (GHz)	Core Bandwidth (GHz)	E_d Stacktail (MeV)	E_d Core (MeV)	Energy Aperture (MeV)	Core Width (MeV)	Fraction Unstacked (%)
2-4	4-8	20	5	77.4	9.6	50%
2-6	4-8	8	5	48.4	9.6	66%
2-6	2-6	8	8	45.2	12.8	55%
4-8	4-8	5	5	33.9	9.6	72%

http://www-bd.fnal.gov/doereview03/Current/02_Pbar_stacking_cooling.pdf

Increasing Maximum Flux

Increase Bandwidth

2-6 GHz

9 MeV gain slope

Maximum flux ~102 mA/hour

New pickups and kickers

4-8 GHz core system

Increase E_d

2-4 GHz

18 MeV gain slope

Maximum flux ~80 mA/hour

Move pickup tanks

2-4 or 4-8 GHz core system

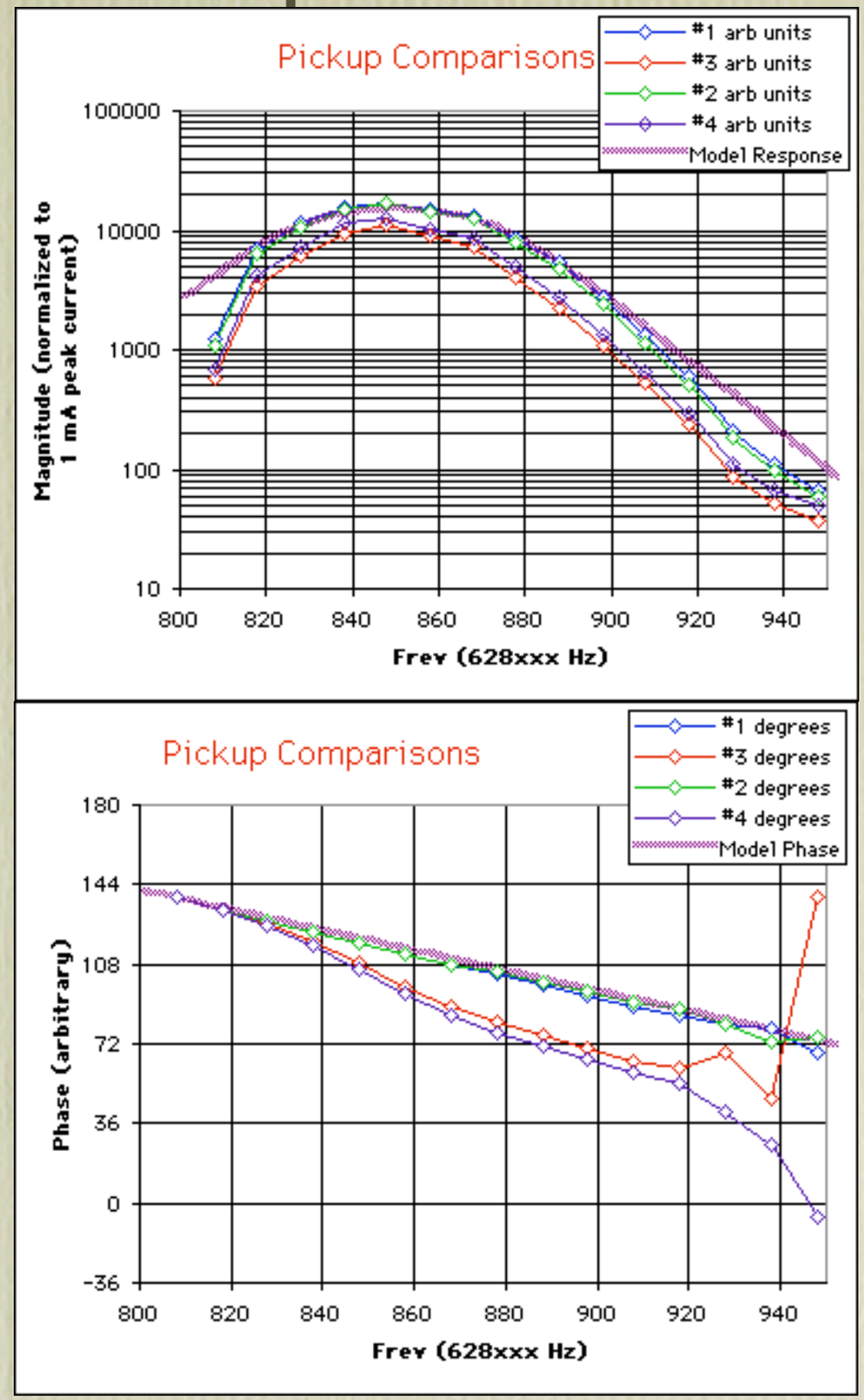
Simulation Model is a numerical integration of Fokker-Planck equation, including Feedback

Two scenarios:
Full bandwidth available & Half bandwidth available

Nota Bene: Half bandwidth at same center gives ~ half maximum rate

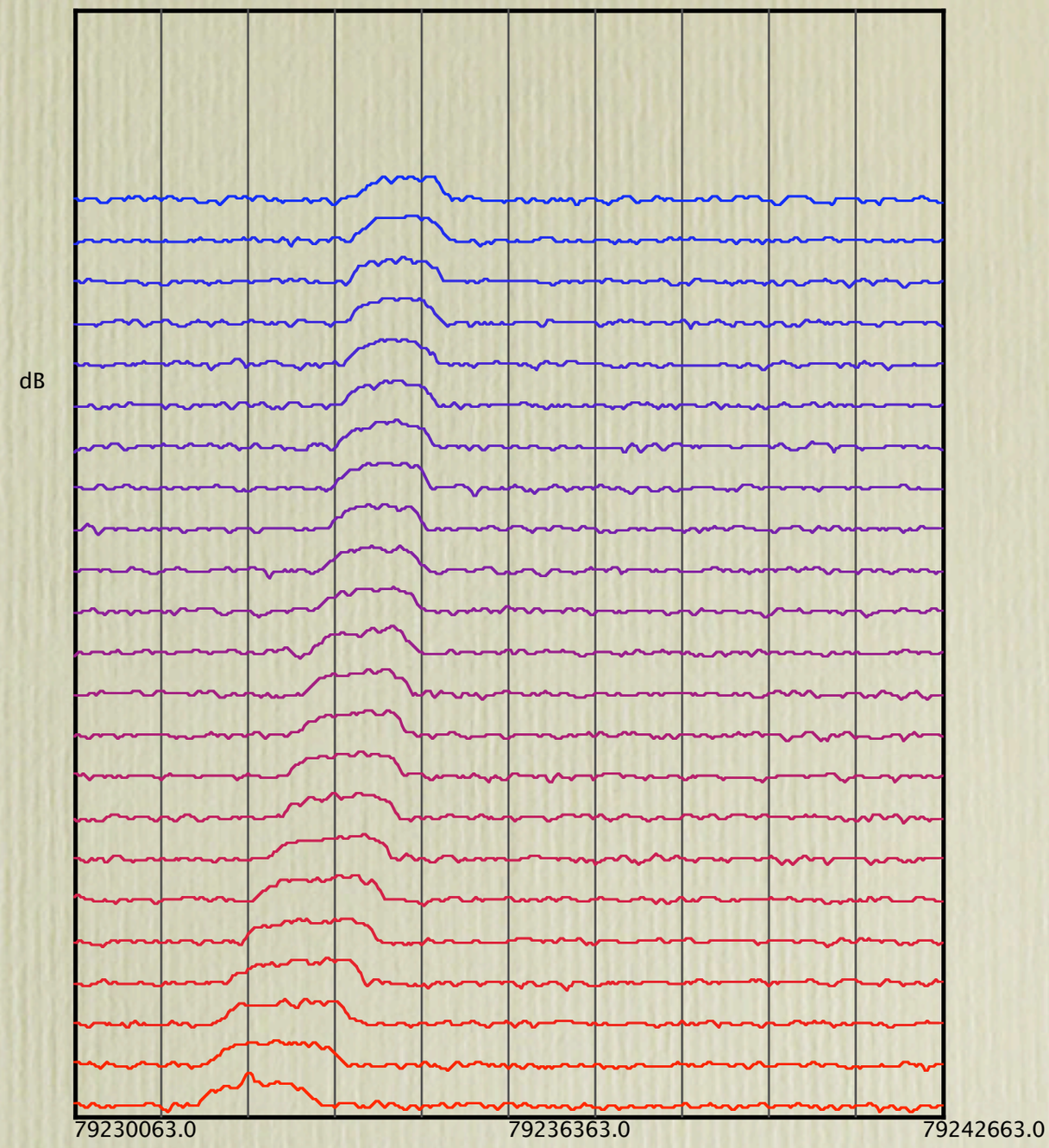
Modelling Pickups

- 1997: Test with 4 pickup designs
  - varying width
  - varying angle
- Compared to model:
  - integrate image charge to calculate response
  - function of aperture, pickup shape
  - Shape and phase well predicted

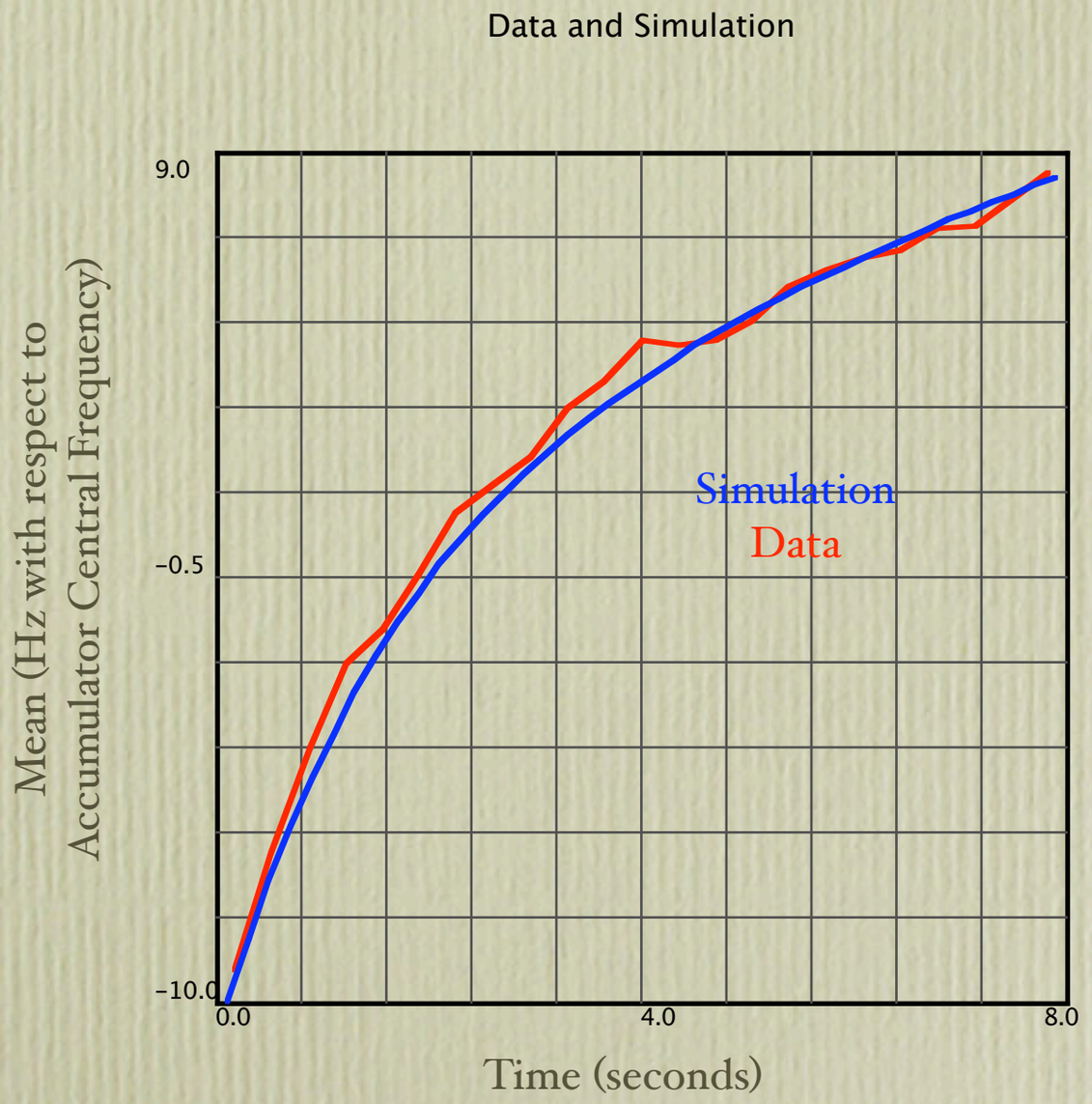


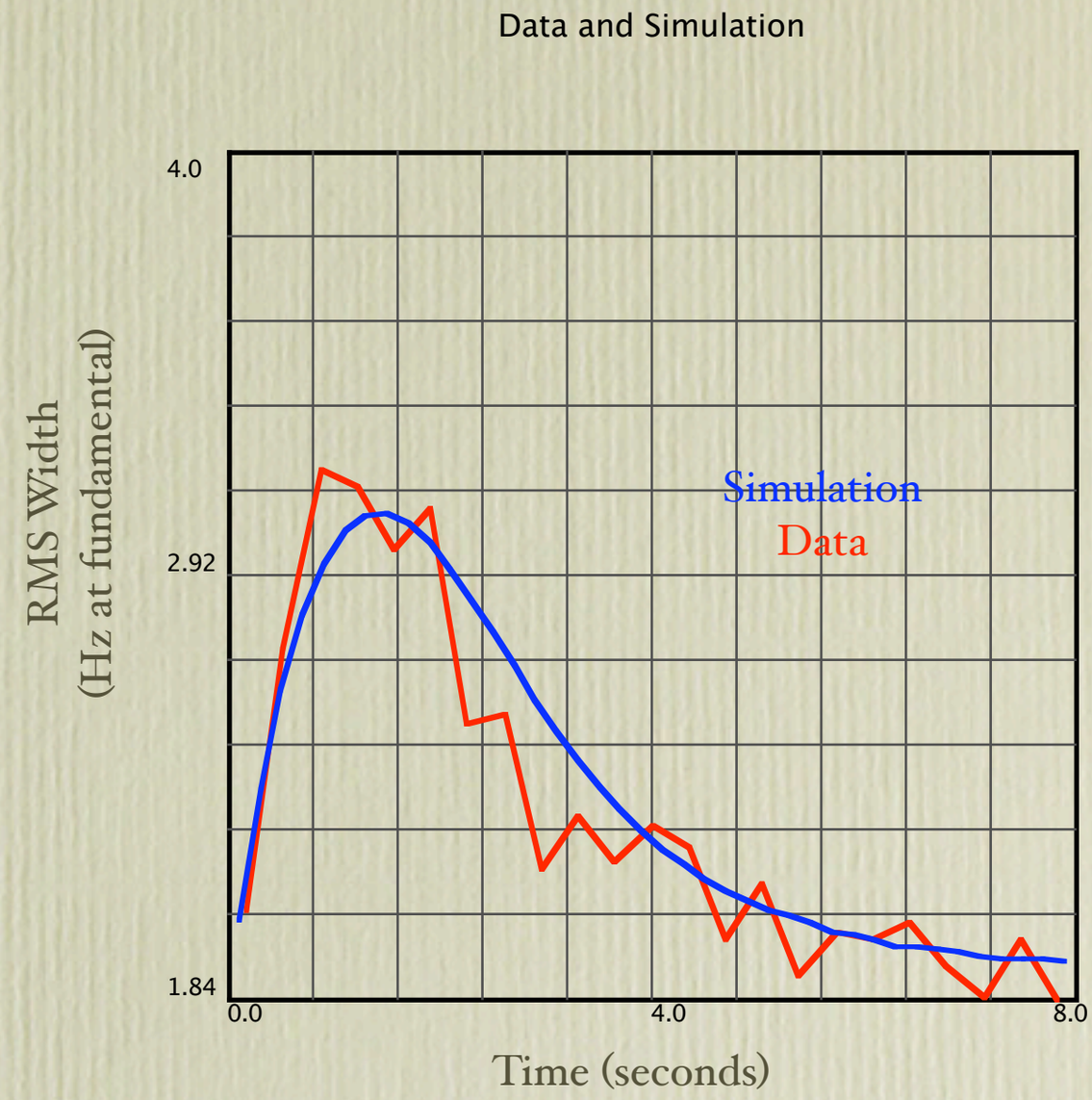
Simulation Tests

- Single Pulse Evolution
  - Track Evolution of:
    - Pulse mean
    - Pulse RMS
- Direct Comparison of simulation and hardware



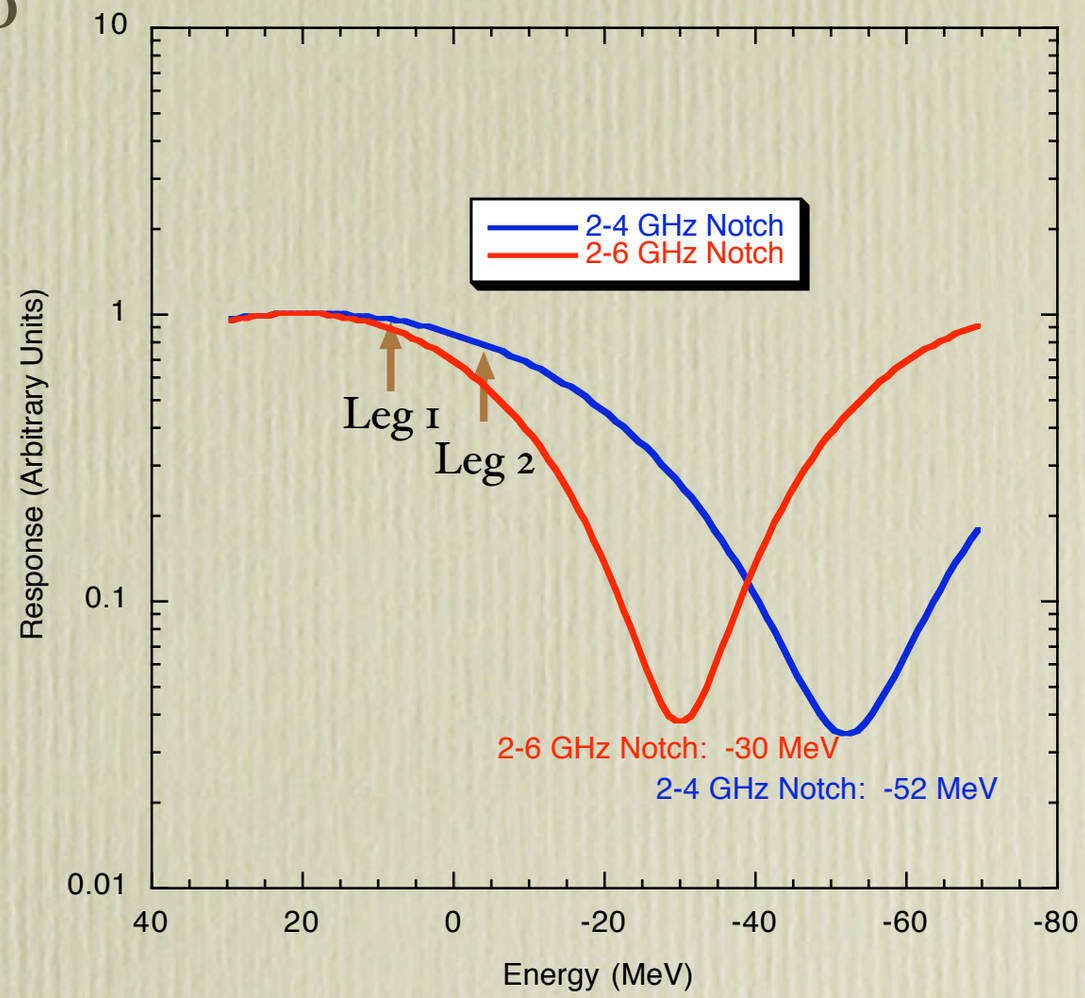
Pulse Evolution





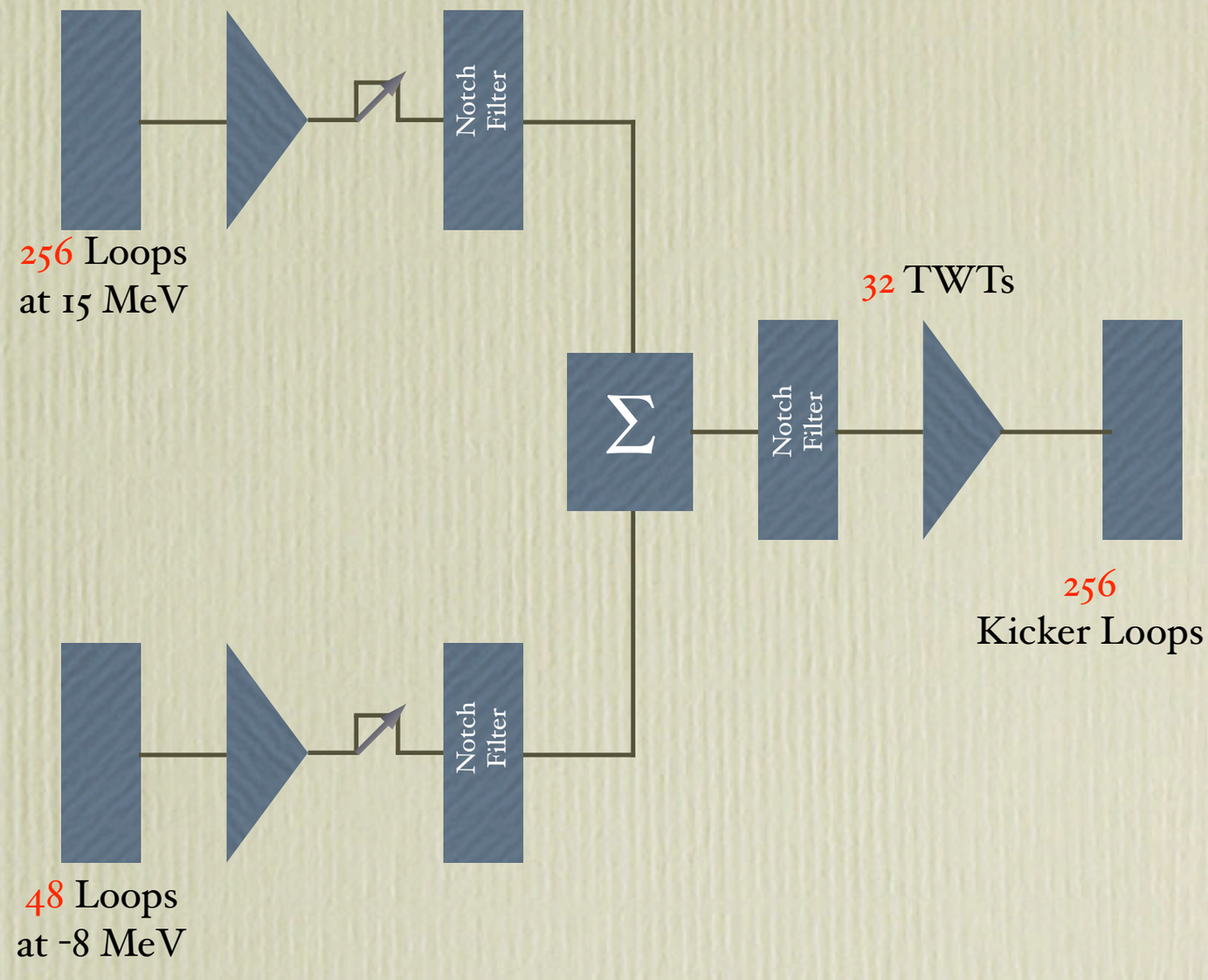
Notch Filters and Energy Aperture

- van der Meer solution: exponential gain leads to constant flux
- WANT TO STOP AND ACCUMULATE!
- Null out the stacktail pickup signal
  - convolution of pickup and notch response
- Contributes energy aperture for stacking
  - distance between peak and notch
  - depends on frequency band

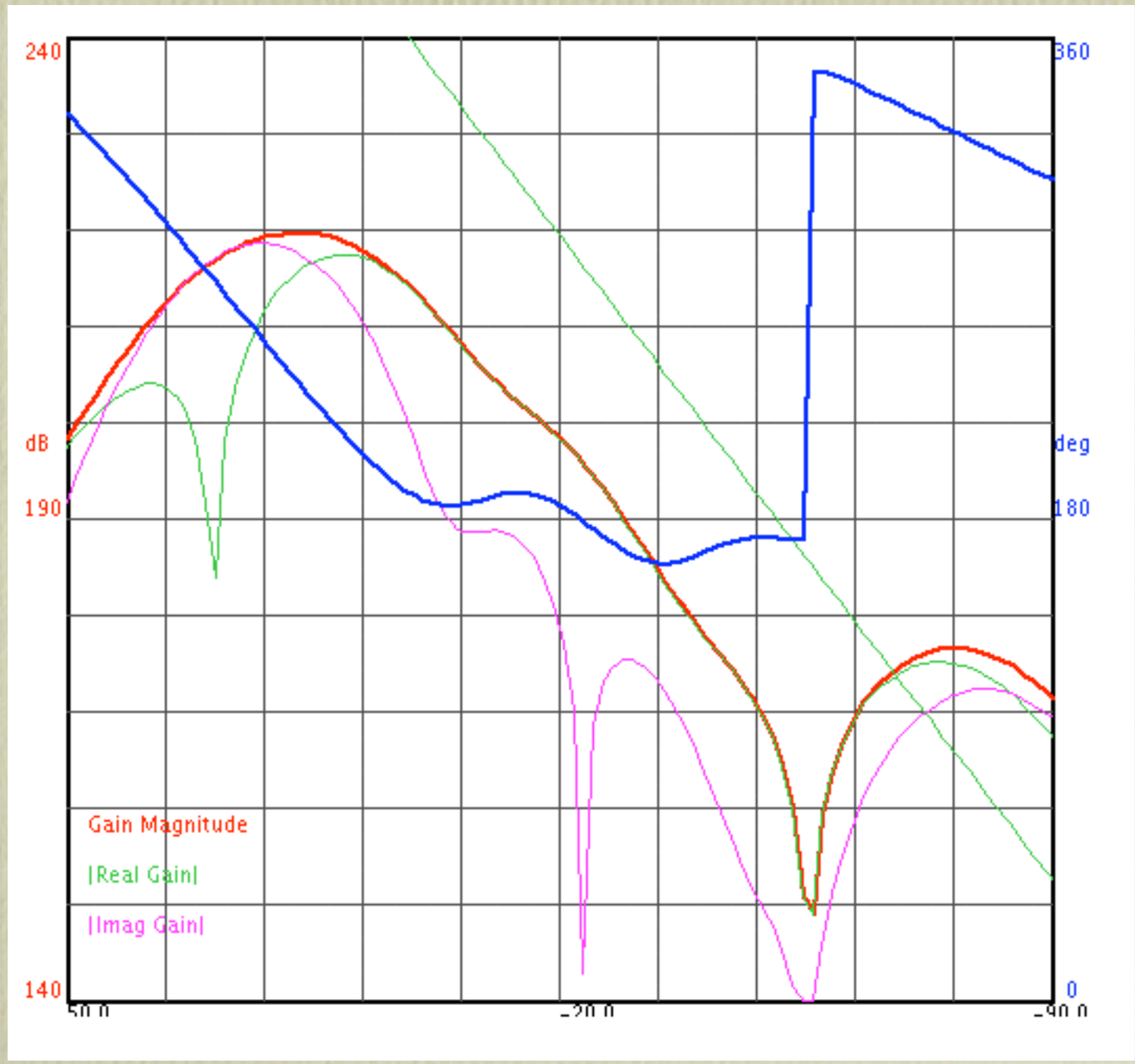


Increase E_d -- tank move option

- Move positions of pickups and change electronics settings to change E_d while keeping 2-4 GHz
  - 1 mm move on 2 tanks (A60-1 & A60-4)
  - 7 mm move on 1 tank (A60-3)
- Target E_d ~18 MeV
  - simulation achieved ~16 MeV
  - to keep good match into core
- Maximum stacking rate ~70 mA/hour

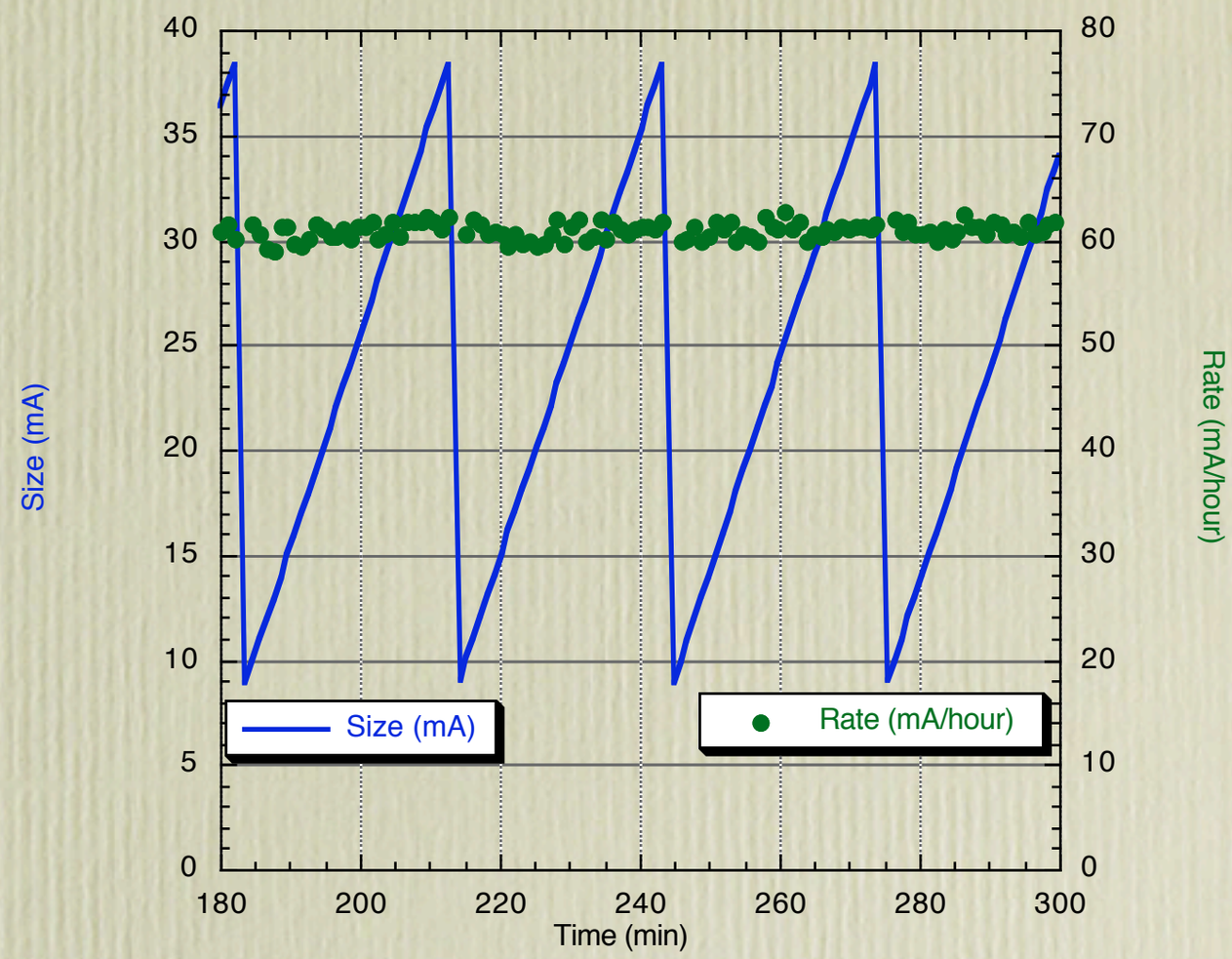


Gain and Phase: Tank move option



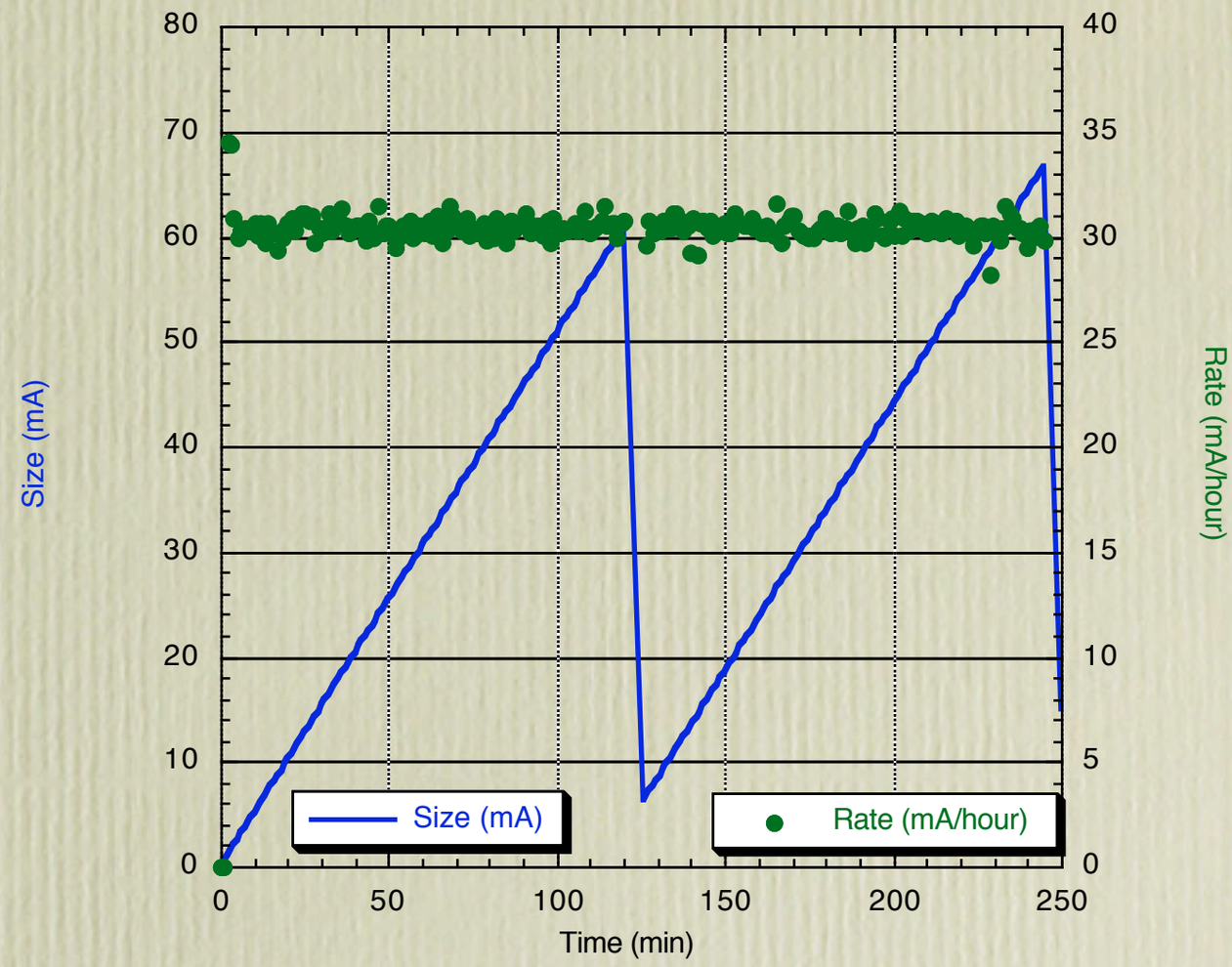
Tank move simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use full bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 60 mA/hour for 30 minutes



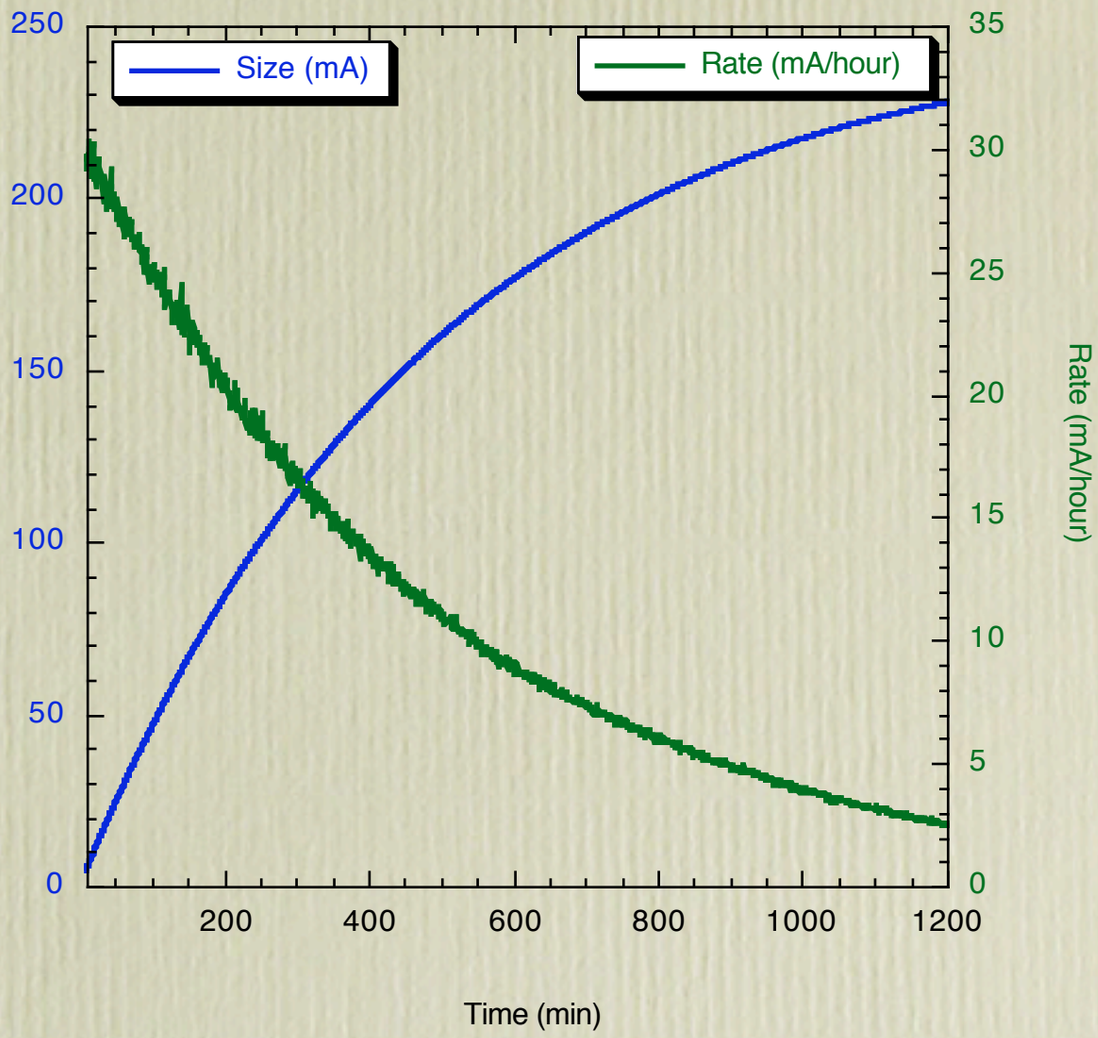
Tank move simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use half bandwidth
- Transfer every 120 minutes, 5.5 minute/ transfer
- Sustains 30 mA/hour for 120 minutes



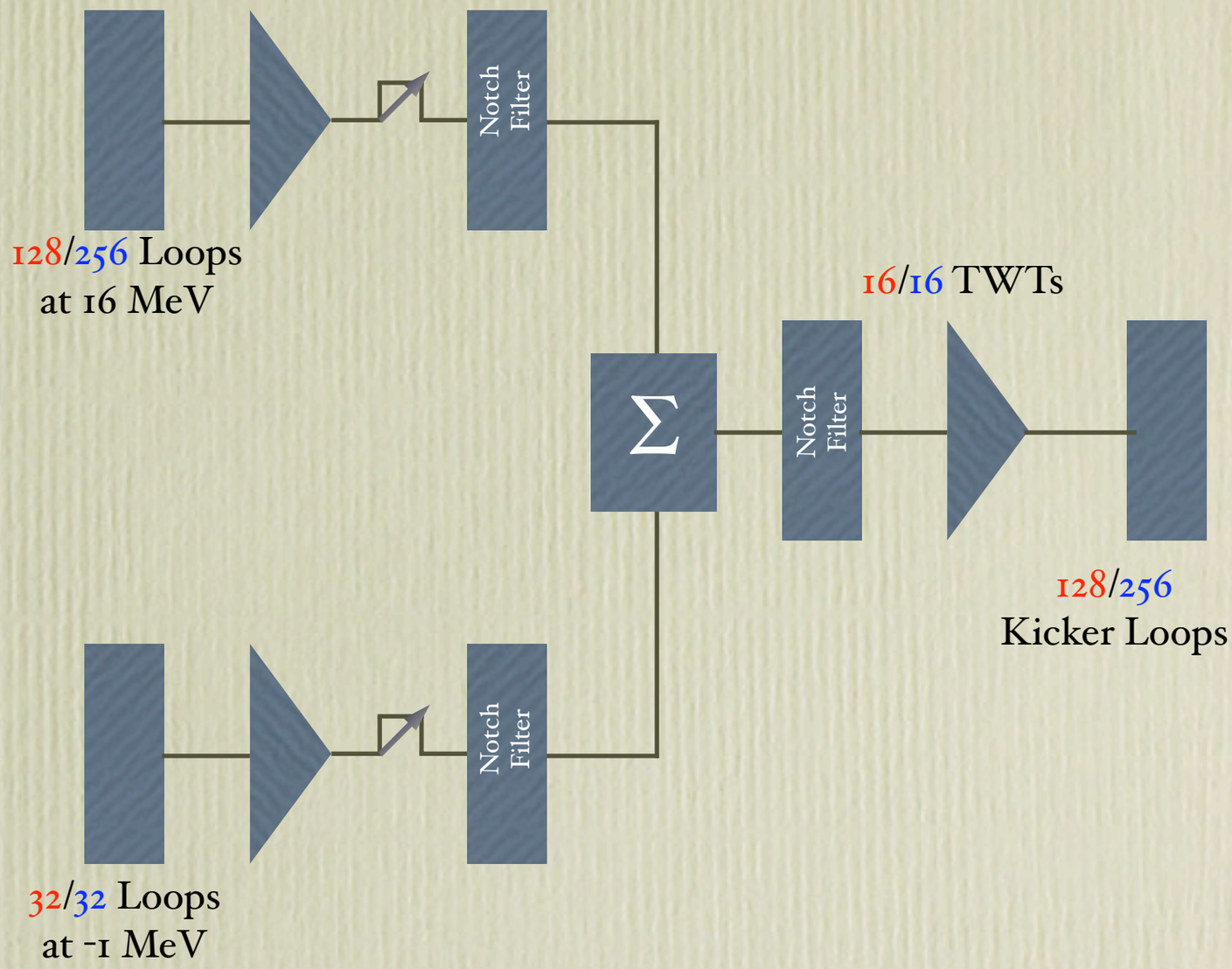
Tank Move Simulation Results

- For Mixed Mode operation, assume rate falls of with size (based on current performance)
  - NUMI sets 2 sec cycle
  - Sample injected beam by varying RF bucket size
- Use Half bandwidth
  - Initial rate 30 mA/hour
  - Falls off linearly with maximum of 250 mA
  - Struggles above 230 mA



Increase Bandwidth

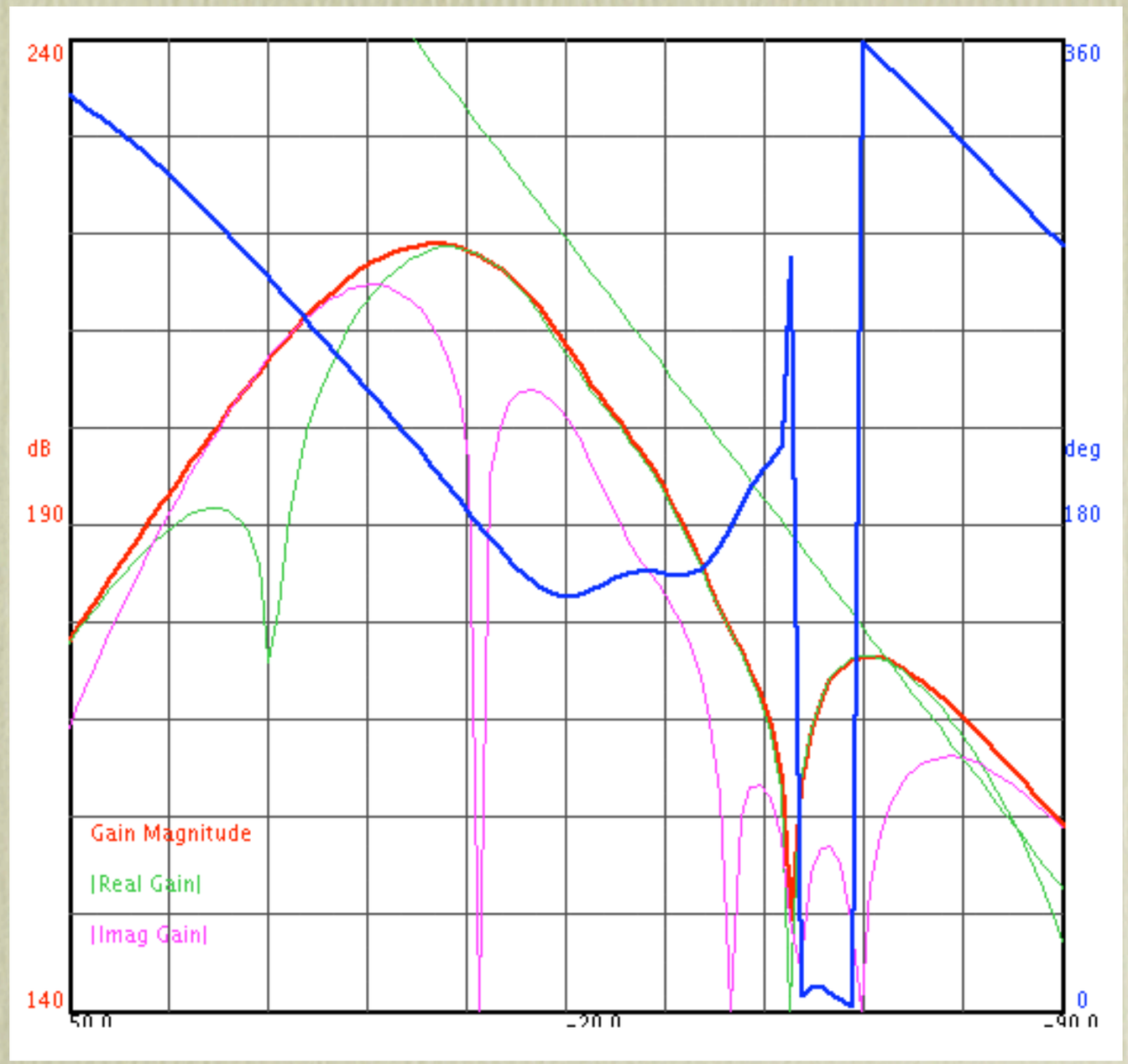
- 2-6 GHz total bandwidth in parallel systems
  - 2-4 GHz band
    - Utilize existing hardware
    - Equivalent to current stacktail
    - Remove $^{1}/_{2}$ system
  - 4-6 GHz band
    - New Hardware
      - Pickup and Kickers
      - Electronics
- Core pickups centered at -30 MeV



2-6 GHz System Parameters

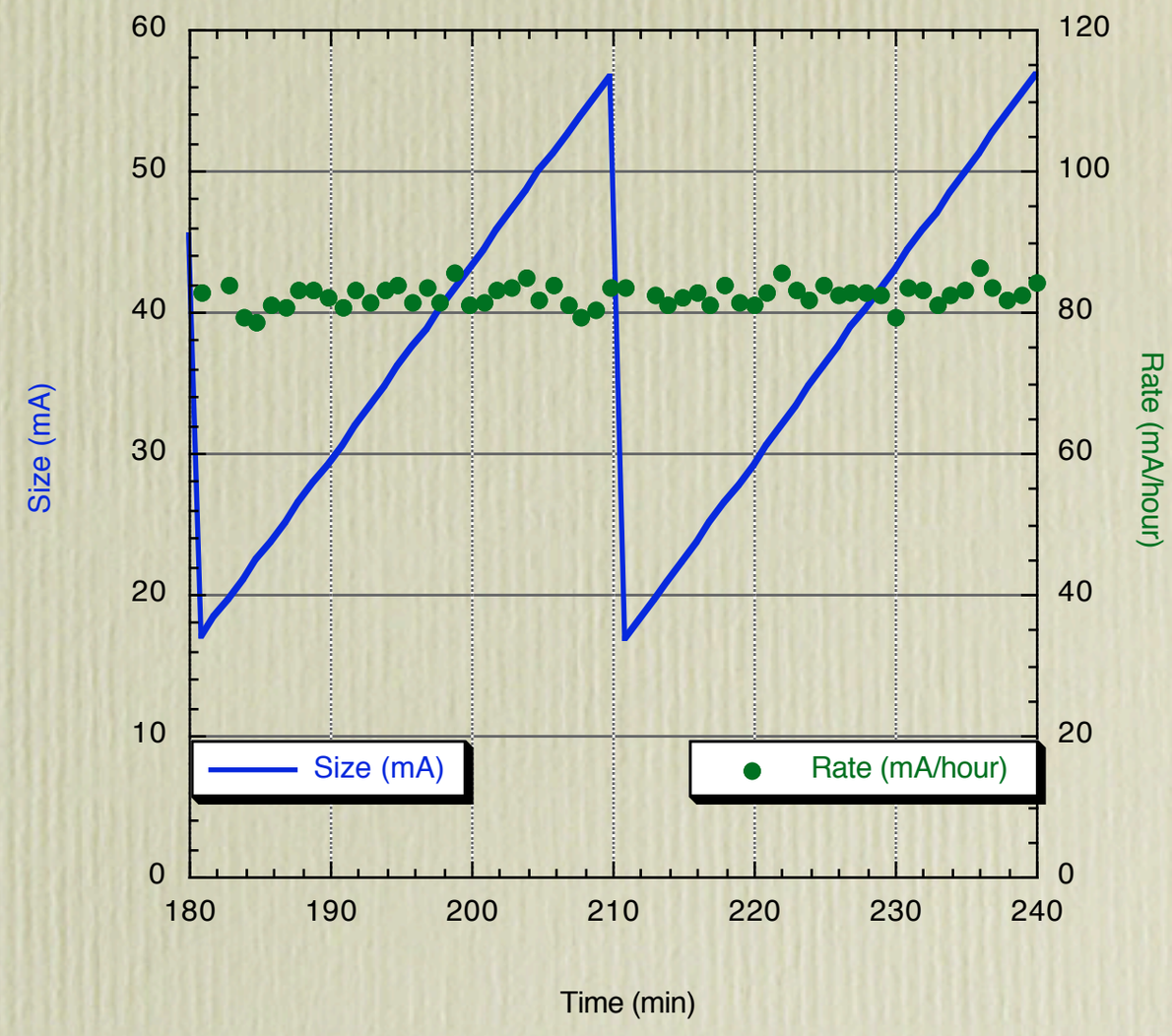
	2-4 GHz System	4-6 GHz System
Pickup Loops	160	288
Kicker Loops	128	256
Loop Impedance	20 Ω	5-10 Ω
Front End Noise Temperature	125 K	125 K
Cryogenic Amps	8	8
1 Watt Amps	8	8
Notch Filters	3	3
TWTs	20	20
TWT Power Supplies	20	20
Total Power	~500 W	~500 W

Gain and Phase 2-6 GHz design



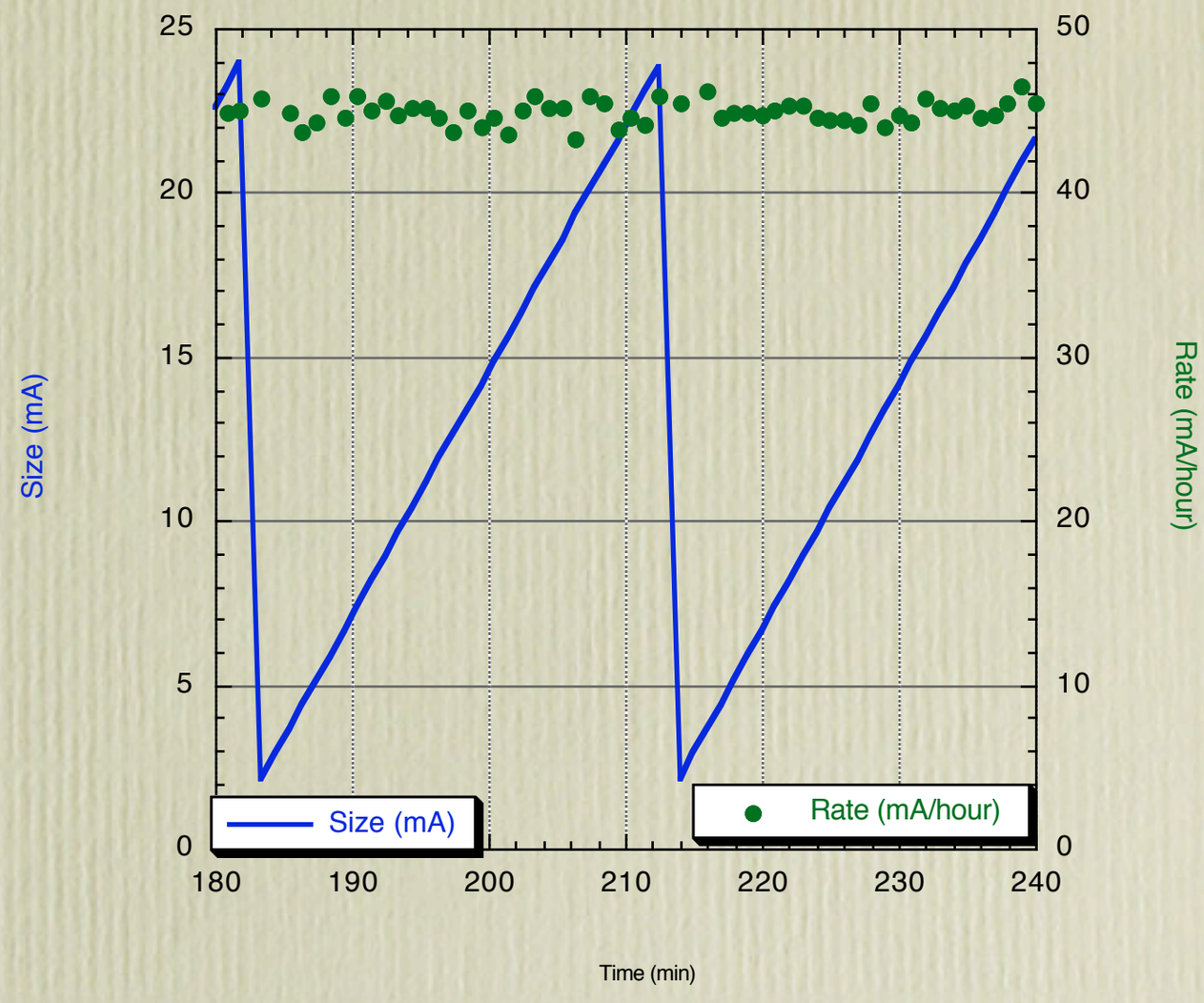
2-6 GHz simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use full bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 80 mA/hour for 30 minutes



2-6 GHz simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use half bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 45 mA/hour for 30 minutes



Summary

- Increase Stacking rate
  - via Bandwidth: can handle up to 80 mA/hour
    - significant hardware upgrades
    - pickups, kickers, electronics in 4-6 GHz region
      - Ralph & Ding on electronics aspects
      - Joel on mechanical aspects
  - via E_d: can handle up to 60 mA/hour
    - moving pickup positions (through moving tanks) and ajdusting electronics settings
  - dependent upon Recycler being final repository